Performance Analysis of Deep Learning Models for Heart Segmentation in Chest X-ray Images on a Small Dataset

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Abstract. **The widespread practice of screening of the lungs by radiography makes it possible to analyze the chest area for the presence of extrapulmonary pathologies, such as cardiac pathologies. In many cases, it is advisable to assign the process of solving the problem of analyzing and marking up images to automated algorithms. This paper discusses the performance comparison of multiple deep learning models for heart segmentation on chest x-ray images. The information obtained can be used to improve the algorithms for recognizing pathologies in chest X-ray images.**

Keywords: **Deep Learning, Neural Networks, Computer Vision, Automation, Radiology, Computational Experiment**

I. Introduction

Due to the wide practice of lung screening by the method of chest radiography, extensive databases of chest X-ray images have been accumulated and there is a possibility, using these databases, to diagnose extrapulmonary pathologies.

Despite the rather long history of image recognition systems [1], they still have not received widespread acceptance. This is largely due not only to insufficient technical development, but also to a lack of systematized knowledge in specific areas [2], which can be overcome by using deep learning methods (neural network methods) along with large amounts of data [3].

The processing of the entire volume of the obtained images and their diagnosis for a wide list of pathologies are complicated for medical institutions by the limited resources. In this regard, it is advisable to use the automation of segmentation and recognition processes, which already at the first stages of technology development makes it possible to redistribute the attention of doctors, focusing their attention on potentially pathological cases and returning attention to cases mistakenly identified as non-pathological.

One of the ways to create an algorithm for the automatic analysis of heart pathologies on X-ray images of the chest is the use of neural networks. To train such models, a large amount of labeled data is required, which is not always available. In this paper, we consider the case of using a small dataset of marked up images (100 pieces) for marking (segmentation) a larger images dataset (more than 2 million images), which has only textual data on pathologies. That can be used for further semi-automatic images segmentation.

Checking the impact of the training model hyperparameters on the result obtained during segmentation can help to reveal some patterns and indicate the disadvantages of the approaches chosen for the algorithm for the automatic analysis of heart pathologies on X-ray images of the chest.

II. Data

To train the models, an open database of annotated chest X-ray images from General Blockchain Inc, originally associated with COVID studies, containing 100 images of various resolutions, was used (Fig. 1). An example of an image with a superimposed mask, rescaled to an aspect ratio of 1:1, is shown in Figure 1. For testing, an image database obtained from two clinics of the Republic of Belarus was also used. From it, a sample of 70,000 images was made, containing 35,000 images with diagnosed cardiomegaly and 35,000 images of healthy hearts (Fig. 2). All images were converted to 512x512 resolution, because under these conditions, the model did not rest against memory and performance limitations, and the result when working with this resolution turned out better, in comparison with the 256x256 resolution.

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The peculiarity of this dataset is that the images for the final tests and the images for training were obtained on different equipment and their quality varies.

Fig. 1. Sample from the training set

The computational experiment was carried out on a computer equipped with an Nvidia RTX2070 video card (8 GB of video memory). Each run took 1-30 minutes, depending on the number of epochs, the number of neural network layers, and other features of each launch.

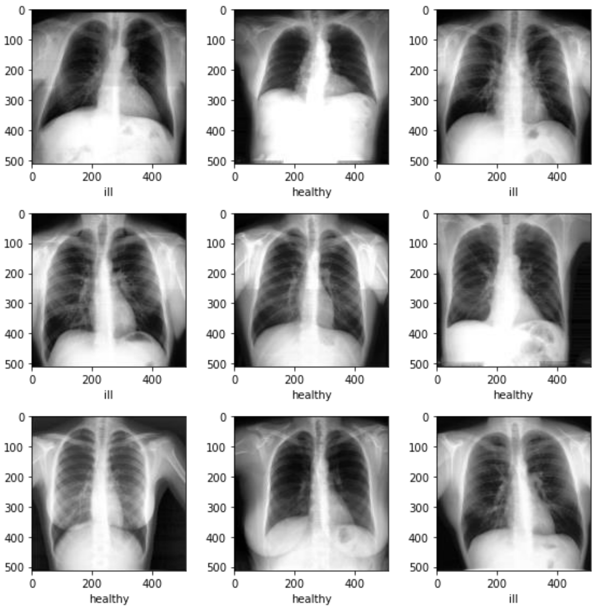

Fig. 2. Samples of used X-ray images

Several preparatory algorithms have been developed using Python, the SQLite language and UNet deep learning model variations to provide cardiac segmentation on chest X-ray images. The operation of this algorithm can be divided into several stages: preparing a dataset by groups of interest in the SQLite database, collecting images by groups of interest in local image databases with simultaneous image preprocessing, training on the collected data in turn by all prepared training models.

III. Performance comparation

The launch of training UNet, Simple ASPP, SegResNet, SegResNetVAE, DynUNet, VNet, RegUNet of neural network models showed the greatest promise of using UNet.

The effect of changing size of region of interest (ROI) was also investigated. Below are the masks generated by the trained model for four chest x-ray images (Fig. 3).

a) ROI = 96x96

b) ROI = 384x384

c) ROI = 448x448; with cropping the result

d) Best ROI, U-Net 16-2048 configuration

e) Using residential units and cropping the result

Fig. 3. Examples of the obtained masks for images that were not involved in training

At the stage of analyzing the impact of ROI changes, UNet was used in the configuration: 64, 128, 256, 512, 1024.

The behavior of the segmentation algorithm when using ROI of different sizes aroused interest. So, in the case of ROI = 96x96 (Fig. 3.a), the neural network learned to exclude from the mask only areas with a much lower density, creating a mask for the entire extrapulmonary region, despite learning from heart masks.

The case with an increased ROI up to 384x384 (Fig. 3.b) is characterized by an increase in the sensitivity of the neural network, more parts of the image were removed from the mask.

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Adding an image cropping stage at the training stage before evaluating the accuracy at ROI = 448x448 (Fig. 3.c) increased the focus on the heart region, but reduced the integrity of the image data perception by the algorithm, which resulted in a slightly changed nature of the resulting masks.

Further optimization of the neural network parameters led to an increase in the number of UNet layers from 5 to 7, namely to the following configuration: 16, 64, 128, 256, 512, 1024, 2048. This configuration already allows us to achieve visually [4] and numerically better results (Fig. 3.d). Adding residential units (Fig. 3.e) further improves the quality of the resulting masks and reduces the number of large elements. At the last stage, it is possible to use basic algorithms for removing small elements and smoothing shapes to achieve a better result, but since the purpose of this work was only to study the behavior of models, such algorithms were not used.

Typical masks obtained by the latest model, the neural network, which showed the best result, are shown in Fig. 4. Despite the small amount of training data, it was possible to approach a satisfactory result.

a) healthy

b) ill

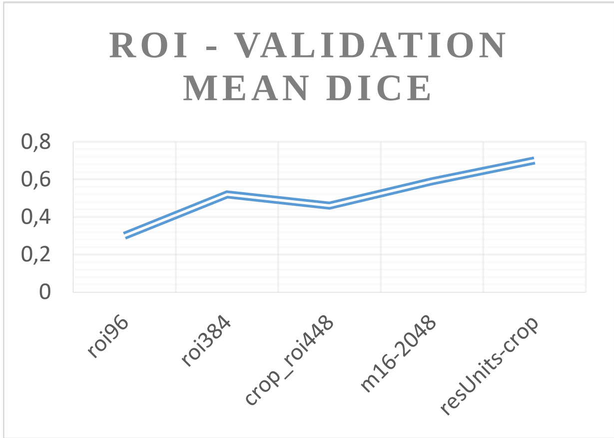
Fig. 4. Best results

The graph for all the described models is shown in Fig. 5. The best final result on the Dice-metric was 0.8484, losses -0.2983. The progress graphs of the learning model can be seen in Fig. 6.

IV. Conclusion

The results of these experiments can be used for automatic and semi-automatic segmentation of the heart region on X-ray images of the chest, i.e. to expand the database of the marked-up data, which partially solves the problem of the availability of such data. The trained neural network can be used as a stage in training new models [5]. This data can also be used to build more accurate models of heart segmentation and classification of heart diseases, subject to additional image processing with standard computer vision algorithms and additional training of the model with updated output masks. Also, retraining of pre-trained models can be a promising way to improve performance [6].

a)



b)

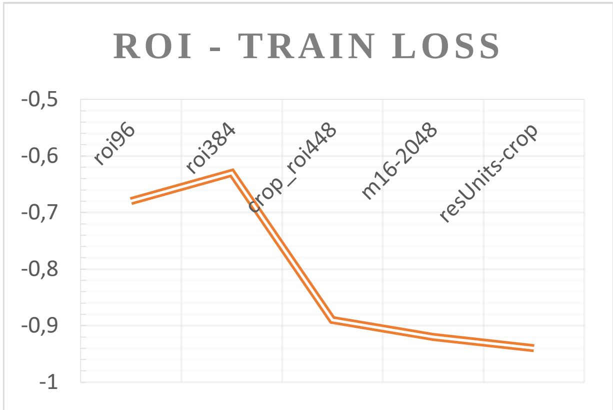
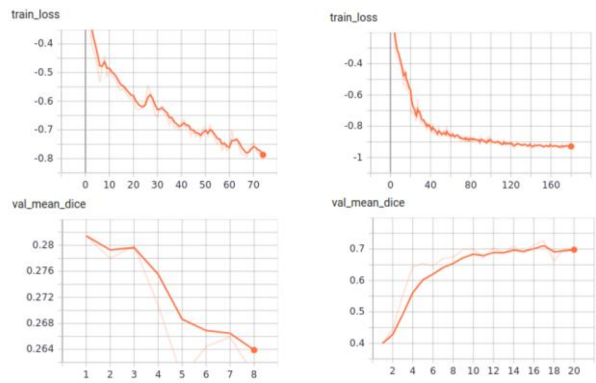


Fig. 5. Comparison of the considered models



Low ROI Balanced ROI

Fig. 6. Evaluation of results in the learning process

In the future, it is planned to work on an algorithm for the detection and classification of extrapulmonary pathologies on X-ray images of the chest, where the obtained information and results will be applied.

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